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Twenty-first day of December 1999

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MANAGER PATENT OPERATIONS

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AUSTRALIA

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# PROVISIONAL SPECIFICATION

**Applicant(s):**

THE UNIVERSITY OF SYDNEY

**Invention Title:**

SUPPRESSION OF SELF PULSATIONS IN DFB FIBRE LASERS

The invention is described in the following statement:

# SUPPRESSION OF SELF PULSATIONS IN DFB FIBRE LASERS

## Field of the Invention

The present invention relates to intensity pulsation in distributed feedback (DFB) fibre lasers and, in particular, discloses a method and apparatus for the suppression of their occurrence.

## Background of the Invention

The utilisation of optical fibre networks in telecommunications is becoming more and more prevalent due to their high and expanding bandwidth capabilities. Further, with the recent introduction of erbium doped fibre amplifiers (EDFA) wavelength division multiplexing (WDM) systems are being introduced so as to multiplex multiple channels. The increase in WDM density places more stringent requirements on the principles of operation. This requires laser transmitters with accurate wavelength selection and high wavelength stability, in addition to low power output fluctuations.

Fibre lasers in general are ideally suitable as they are fully fibre-compatible allowing for very low coupling losses. The DFB fibre laser particularly has a number of additional advantages over their semiconductor counterparts. The potential of DFB fibre lasers as low noise, narrow linewidth sources for WDM systems has been demonstrated recently in digital transmission tests. Further, with a passive temperature compensated package, the wavelength stability of DFB fibre lasers could be set better than 1 GHz within -20/+80°C temperature range.

The origin of self-pulsations in Er-doped distributed-feedback (DFB) fibre lasers is related to ion clustering at high erbium concentrations [Sanchez et. al. Phys. Rev. A, 48(3), 2220-2229]. The clusters act as saturable absorbers with switching time much shorter than the population inversion recovery time and can eventually result in spiking behaviour of the laser. Reducing the erbium concentration while still providing enough gain in a short cavity DFB fibre laser can be achieved by Yb co-

doping [Kringlebotn et. al. IEEE Photon. Technology Letters 5(10), 1162-1164 (1993)] which increases the pumping efficiency. Stabilisation of the laser against self-pulsations can also be accomplished by resonant pumping [Loh et al, Optics Letters 21(18), 1475-1477 (1996)] or co-pumping [Loh et. al. Optics Letters, 22(15), 1174-1176 (1997)] directly into the metastable Er-ion state, damping down the oscillations of the population inversion.

Summary of the Invention

It is an object of the present invention to provide for a DFB laser having low output level fluctuations.

In accordance with a first aspect of the present invention, there is provided, in a distributed feedback laser arrangement, including a distributed feedback laser portion and a signal amplification portion, a method of reducing fluctuations in the output power of the arrangement comprising the step of: inducing a saturable absorption grating in the arrangement to reduce the fluctuations.

The method preferably can include providing a saturable absorption portion at the end of the signal amplification portion where the saturable absorption portion forms part of the signal amplification portion but produces loss rather than gain.

The signal amplification portion can be in a feedback loop with the distributed feedback laser portion and the feedback loop can be formed by coupling a portion of the output of the signal amplification portion to the distributed feedback laser through the process of four-wave mixing in the saturable absorber section.

The distributed feedback laser portion and the signal amplification portion are preferably formed from Erbuim doped fiber.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms

of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a schematic illustration of the arrangement of the preferred embodiment;

Fig. 2 illustrates the dynamics of the laser output with and without feedback;

Fig. 3 illustrates power distribution along the power amplifier at 47mW of launched 980nm pump power.

Fig. 4 illustrates the laser line width measured with and without feedback.

Description of Preferred and Other Embodiments

In the preferred embodiment, a feedback signal from a self induced absorption grating in an under pumped section of a separate Er-doped fibre is utilised to suppress self-pulsing behaviour of an Er-doped DFB fibre laser.

Turning initially to Fig. 1, there is illustrated the preferred arrangement 1 in which a 6cm long DFB structure was written in an erbium doped fibre. The DFB was pumped by a 980nm pump 3. The DFB structure 2 absorbed only approximately 20% of the launched pump power producing approximately 0.5mW of output. The rest of the pump power was used to pump a section of low concentration Er-doped fibre 4. The fibre was available commercially as EDF-2 from Redfern Fibres of Australian Technology Park, Redfern, NSW, Australia. The EDF section 4 acts as a power amplifier to scale the laser output of DFB laser 2 to approximately 10mW.

The DFB master oscillator 2 was not isolated from the amplifier section 4 and its performance was affected by an intentionally induced feedback provided by a low reflectivity loop mirror 5 which was based on a coupler 6 which provided a 3% output coupler in ratio. The feedback provides a counter propagating wave in the power amplifier.

The technique of suppressing output oscillators relies on the process of saturable absorption at the end of the amplifier section 4.

Without the feedback from the mirror, the laser exhibited self-pulsations and operated in cw mode when the mirror was in place (Fig. 2). Since a long section of the power amplifier was under-pumped (Fig. 3) an absorption grating was formed there by the interference pattern of the counter-propagating waves due to the saturable nature of the absorption in Er-doped fibres. The unique filtering properties of such a grating have been described in (5) and its phase sensitivity is particularly important for the present case. The process of four-wave mixing ensures that the feedback signal is phase-conjugated to the DFB output, eliminating the effect of environmental perturbations on the phase of the feedback signal. The amplified feedback signal provides resonant pumping as well as saturates gain the DFB to the threshold value, damping down relaxation oscillations in the population inversion. Additionally, the DFB is injection locked to the feedback signal which is always within he locking range of the laser. Alternatively, the laser can be viewed as a four-mirror cavity, which can be described using the approach suggested in (6). In the present case the filtering effect is primarily related to the phase discrimination properties of the absorption grating which discriminates the modulation sidebands (Fig. 4) with respect to the carrier frequency since they are not necessarily correlated in phase.

It would be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiment without departing from the spirit or scope of the invention as broadly described. The present embodiment is, therefore, to be considered in all respects to be illustrative and not restrictive.

We Claim

1. In a distributed feedback laser arrangement including a distributed feedback laser portion and a signal amplification portion, a method of reducing fluctuations in the output power of said arrangement comprising the step of:
inducing a saturable absorption grating in said arrangement to reduce said fluctuations.

2. A method as claimed in claim 1 wherein said method includes providing a saturable absorption portion at the end of said signal amplification portion.

3. A method as claimed in claim 2 wherein said saturable absorption portion forms part of said signal amplification portion but produces loss rather then gain.

4. A method as claimed in any previous claim wherein said signal amplification portion is in a feedback loop with said distributed feedback laser portion.

5. A method as claimed in claim 5 wherein said arrangement is formed in optical fibre and said feedback loop is formed by coupling a portion of the output of said signal amplification portion to said distributed feedback laser.

~~6. A method as claimed in any previous claim~~ wherein said distributed feedback laser portion and said signal amplification portion are formed from Erbuim doped ~~fiber.~~

7. A method as claimed in any previous claim where feedback loop provides feedback signal phase-conjugated feedback to the distributed feedback laser output.

8. A method as claimed in any previous claim where the feedback signal provides resonant pumping as well as saturates gain in the distributed-feedback laser to the threshold value.

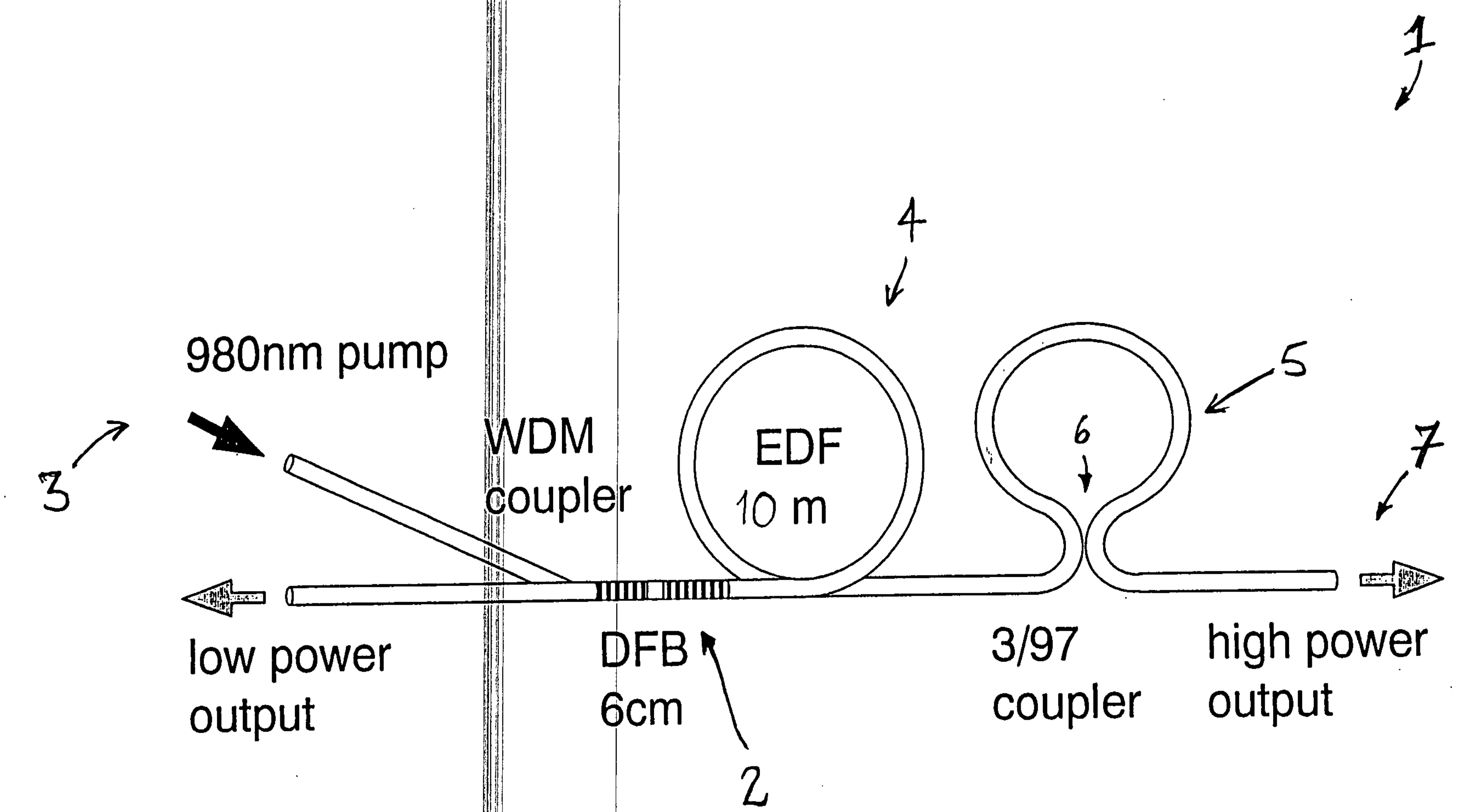

1
980nm pump
3
WDM
coupler
4
EDF
10 m
5
6
7
low power
output
DFB
6cm
2
3/97
coupler
high power
output

FIG. 1

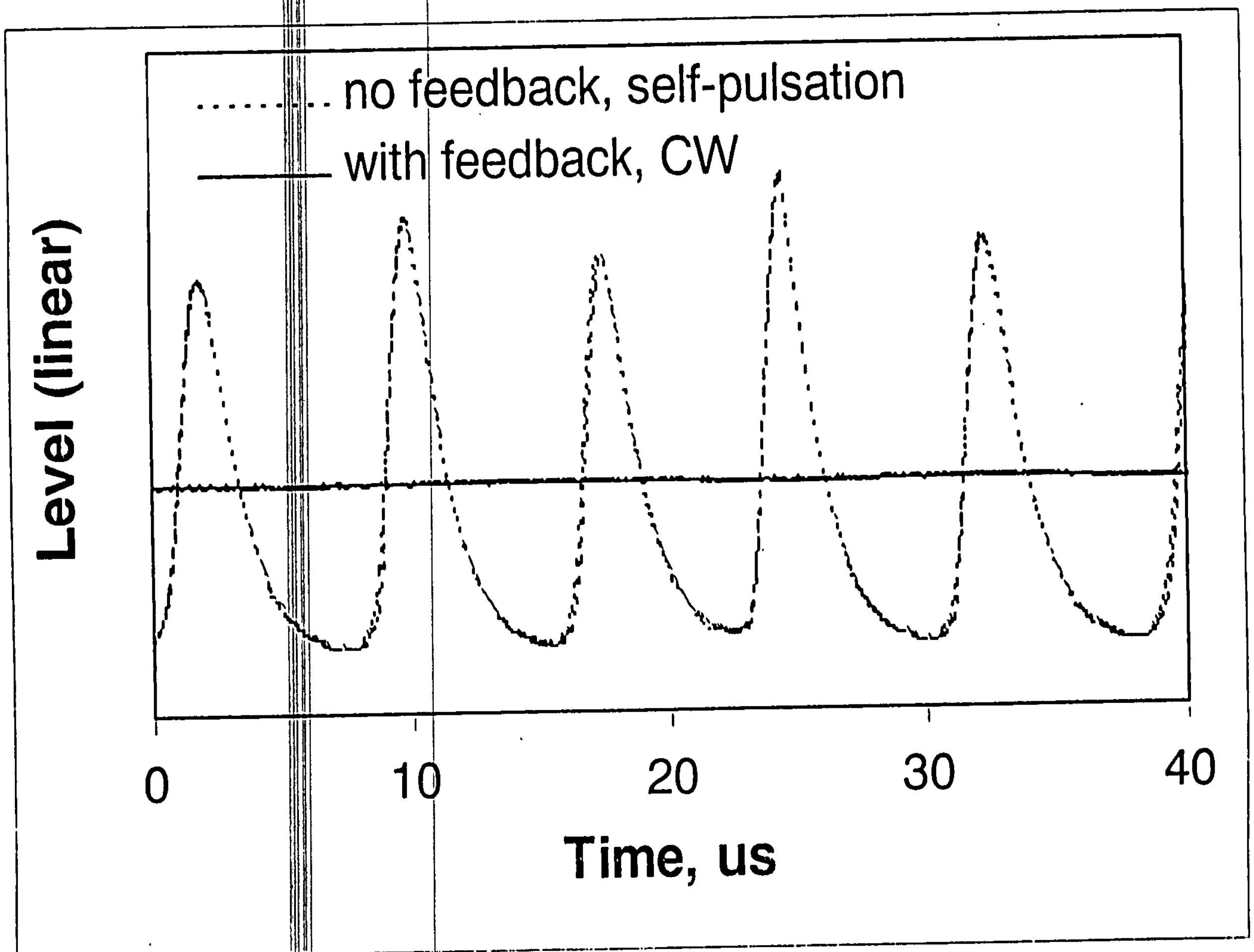
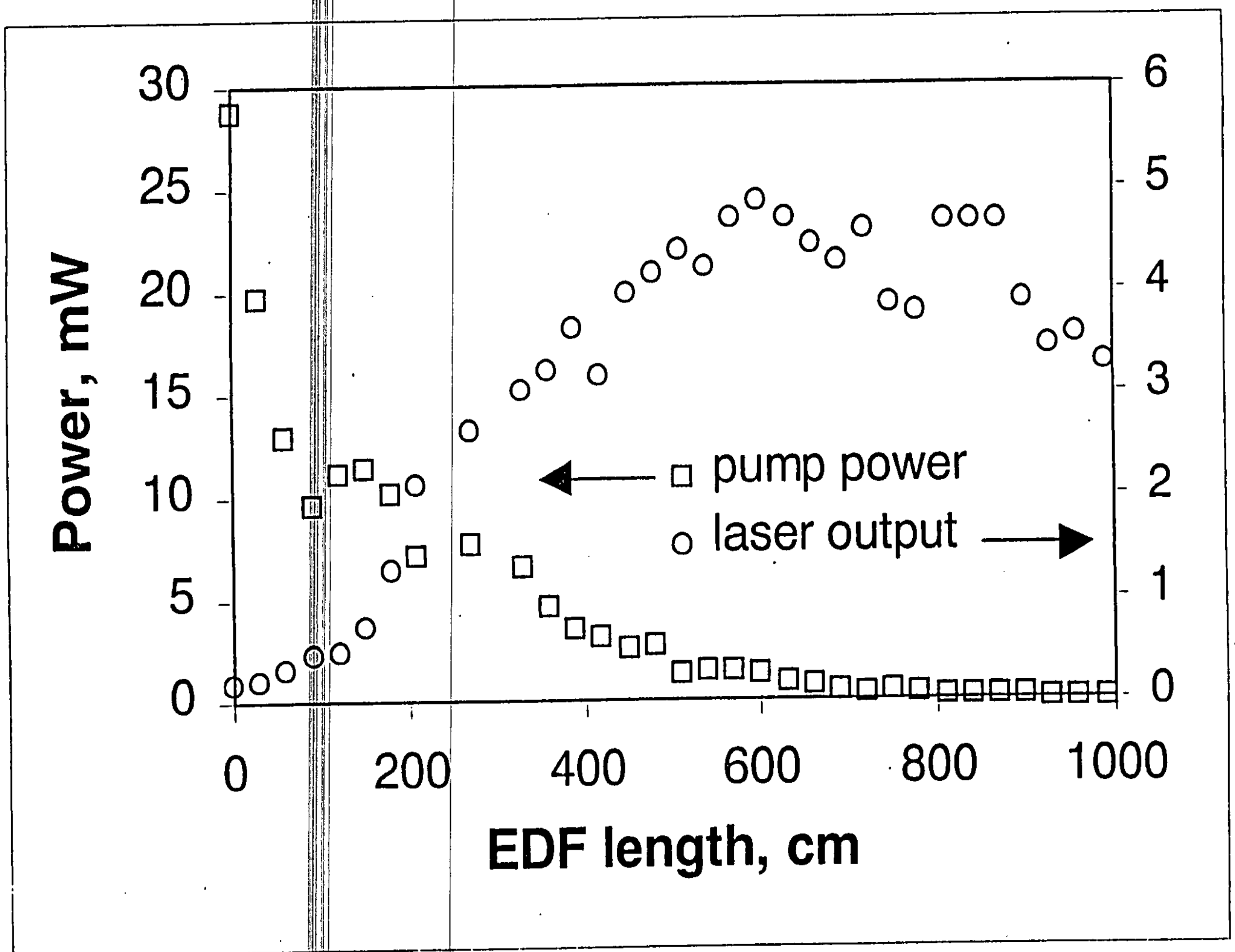
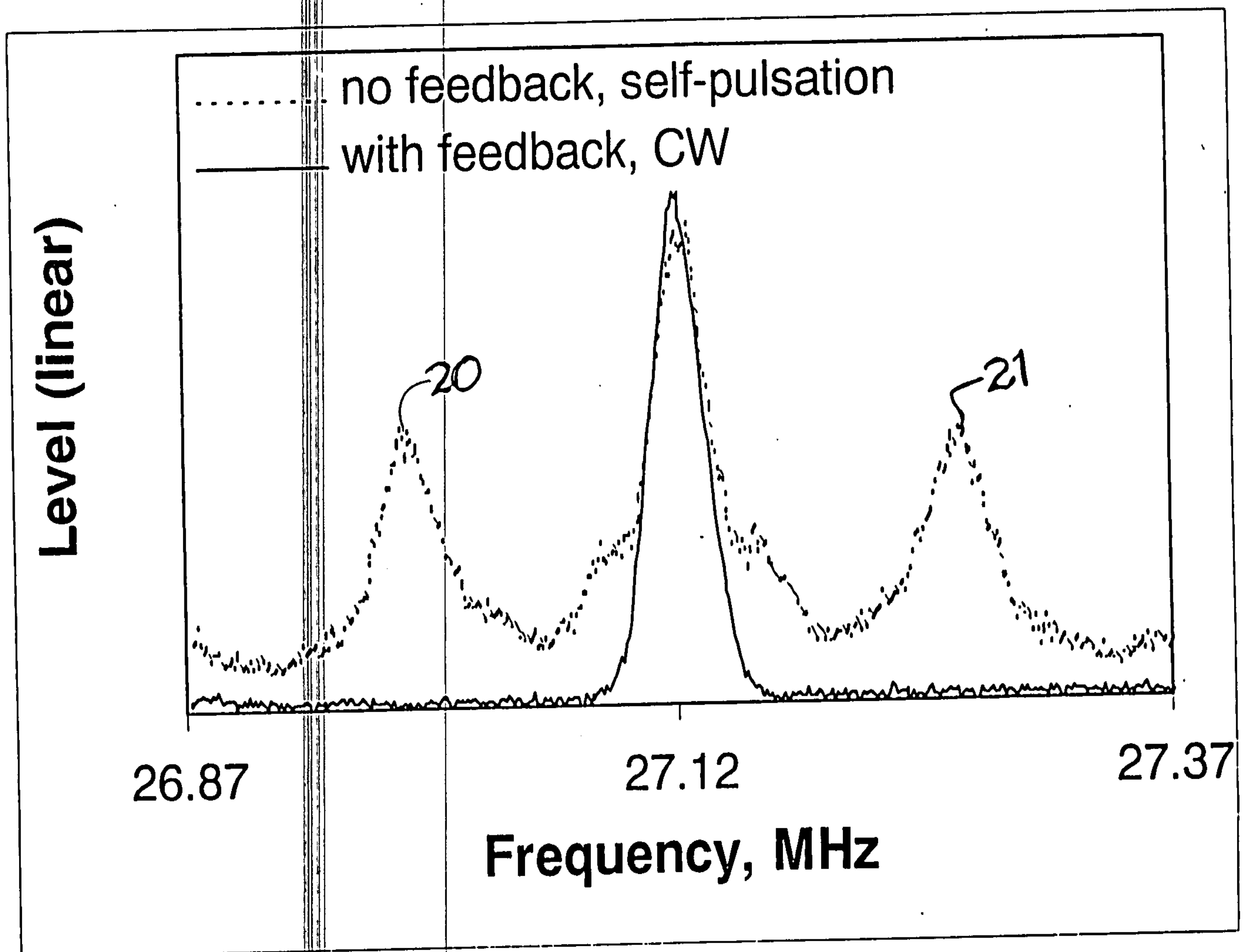

no feedback, self-pulsation
with feedback, CW
Level (linear)
0
10
20
30
40
Time, us

FIG. 2



Power, mW
30
25
20
15
10
5
0
6
5
4
3
2
1
0
0
200
400
600
800
1000
EDF length, cm
pump power
laser output


FIG. 3



no feedback, self-pulsation
with feedback, CW
20
21
Level (linear)
26.87
27.12
27.37
Frequency, MHz


FIG. 4

Abstract

In a distributed feedback laser arrangement including a distributed feedback laser portion and a signal amplification portion, a method of reducing fluctuations in the output power of the arrangement comprising the step of: inducing a saturable absorption grating in the arrangement to provide phase-conjugated feedback signal to the laser arrangement. The method preferably can include providing a saturable absorption portion at the end of the signal amplification portion.